

# **Title: Multi-Element Adjustable Transducer Arrays For Applications With Portable Ultrasonic Flaw Detectors**

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## **Objective:**

- To develop a set of multi-element adjustable ultrasonic transducer arrays for use in a variety of ultrasonic inspection procedures. The arrays will be integrated with the commercially available portable ultrasonic units. The arrays will be utilized to detect and characterize fatigue cracks and corrosion as well as to monitor the sealant quality in the multi-layered airplane structures, from the airplane skin without disassembly. Consideration will be given to combination of multiple measurements into a single information set from multiple zone, multiple depth inspections of aircraft structures.
- To transfer the technology for aircraft industry use

## **Research activities:**

A methodology is being developed to determine an optimal number, types, and spatial orientations of transducer array elements based on the spatial orientations and sizes of aircraft structural elements and defects. Existing or modified measurement models and ray tracing software will be applied to the array design.

A procedure is under development to select a suitable set of commercially available ultrasonic transducers for specific applications. A multi-element transducer-positioning head will include a multi-axial transducer holder with manual controls for rapid adjustments of the transducers' spatial orientations. An optional design of the remotely controlled holder will be also explored.

A flexible coupling unit is also being developed. The unit will be suitable for applications on the curved and non-uniform surfaces. The unit design will provide for a number of interchangeable coupling options including irrigated or dry-coupling flexible membranes. The transducer positioning head and the coupling unit will be integrated into the transducer module. The module design will make it possible to change a footprint of the transducer array based on the inspection requirements and configuration of the inspection area.

A coupling monitoring system will be developed for an automatic monitoring of the array-to-surface acoustic interface. A methodology will be developed for a selection of the commercially available portable ultrasonic units to be integrated with the multi-element transducer arrays. If necessary, hardware interfaces will be developed to facilitate the integration of the selected portable units.

Prototype transducer arrays will be integrated with the selected portable ultrasonic units for demonstration at AANC and validation on the specific application to be identified in conjunction with the FAA technical monitor. The methodology for development and applications of the transducer arrays will be transferred to industry.

## **Anticipated results:**

The arrays developed here will be utilized to detect and characterize small incipient fatigue cracks and corrosion spots, as well as to monitor the sealant quality in the multi-layered airplane structures. The arrays will be suitable for rapid adjustments of elements with different parameters (e.g. central frequency or bandwidth) over a wide range of spatial orientations based on the configuration of the aircraft structure, type of the flaw to be detected, and the inspection procedure. The adjustable transducer arrays will replace currently used single element transducer assemblies that are custom-made for each particular application. The new arrays will require minimal time to be readjusted from one application to another. The arrays will be compatible with the commercially available portable ultrasonic units.

Benefits will come from increasing sensitivity and reliability of ultrasonic inspections for cracks and corrosion by utilizing the set of the multi-element adjustable ultrasonic transducer arrays that are compatible with the commercially available portable ultrasonic flaw detectors. The outcome will enhance aircraft safety and reduce maintenance and repair cost. The application of the arrays will also significantly reduce set-up time and instrumentation cost of various ultrasonic inspections thus additionally reducing maintenance cost.

The multi-element ultrasonic systems are considered for a number of the field airframe inspections including specific applications on the DC-10 horizontal stabilizer and Cessna Citation lower wing spars.

## **Accomplishments:**

Potential applications of the multi-element transducer arrays for corrosion and cracks detection in the airplane components were reviewed and discussed with the industrial partners.

Several concepts were explored to design transducer modules using interchangeable elements with variable incident and azimuthal angles. Two models of the transducer units with adjustable incident angles have been developed, manufactured, and tested on the DC-10 and Cessna representative specimens.

Various types of the flexible coupling substrates with different film properties, thickness and shapes were manufactured. The substrates have been evaluated to measure acoustic properties and mechanical performance of the films. The films demonstrated excellent transmission of ultrasonic waves (either with normal incidence or under various incident angles) with center frequencies ranging from 1 MHz to 10 MHz.

Various types of transducer motion for ultrasonic inspection procedures with the conventional contact transducers as well as irrigated and dry-coupled transducers were analyzed. Correlation was established between inspection applications and types of transducer motion.

Two different prototypes of the dry-coupled transducers (with continuous rolling motion and step-like motion) were developed, manufactured, and evaluated.

The dry-coupled transducers have been demonstrated to FedEx, Boeing, and Cessna representatives.